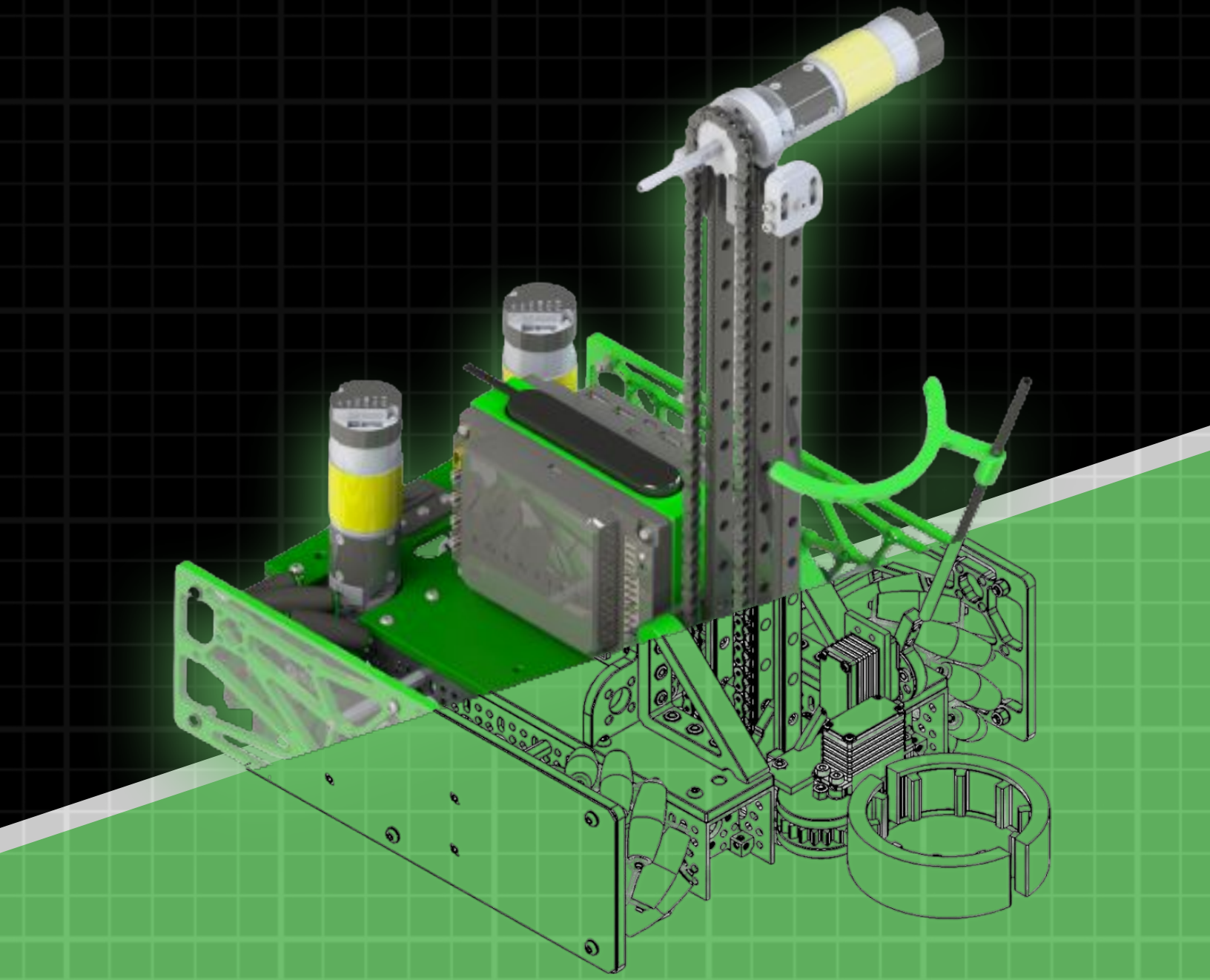
#365

MOE - The Miracle Workerz

ENGINEERING PORTFOLIO



2022 -2023

FIRST TECH CHALLENGE

POWER PLAY

Introduction

WHAT'S INSIDE

Who We Are

MOE 365 is a FIRST® Tech Challenge (FTC) robotics team community-based in Wilmington, Delaware. FIRST® is a global nonprofit inspiring students to become future leaders in STEM through unique, hands-on programs. Each year, we design, build, and program robots to play games released by FIRST® and spread our passion for innovation through outreach. We currently have 11 students in grades 9 to 12 and several adult coaches. MOE stands for **Miracles of Engineering**.

Our Mission:

- Proudly represent ourselves and our partner organizations by exhibiting **FIRST values** of Gracious Professionalism and sportsmanship at all times.
- Inspire **children of all backgrounds to pursue STEM careers** by sharing passion and opportunities through community outreach.
- Strengthen youth and professional **STEM communities** through collaborations and partnerships.
- Build a **cohesive team** based on the respect, communication, creativity, and commitment of all members.
- Develop **student skills** of leadership, professionalism, responsibility, and teamwork.

Meet MOE

STUDENTS

Clare “Clareify”

Project Manager, Marketing Lead

Isha “MOEBuildR”

Build/CAD Team

Jonathan “A MOE-brainer”

Programming Team

Derek “MOEmentum”

Build/CAD Lead

Pranavi “Go with the MOE”

Marketing, Outreach Bot Lead

Ethan “meMOEry”

Programming Lead

Aishwarya “MOEfibrillator”

Marketing, Video and Social Media Lead

Victoria “MOEderator”

Marketing, Sponsorship Lead

Noah “Extra MOEtor”

Build/CAD Team

Suraj “The Garage”

Build/CAD Team

Doris “MOEtivator”

Marketing, Mentorship Advisory Team and Website Lead

COACHES

Ron Prettyman
Lead Coach

Favorite Part: “Helping kids develop life skills to use for the rest of their lives.”

Andrew Szeto
Jack of All Trades

Started the journey for MOE 365 (13 years ago!)

Susan Ho
Parent Coach

Helps with outreach, scheduling, and everything in between!

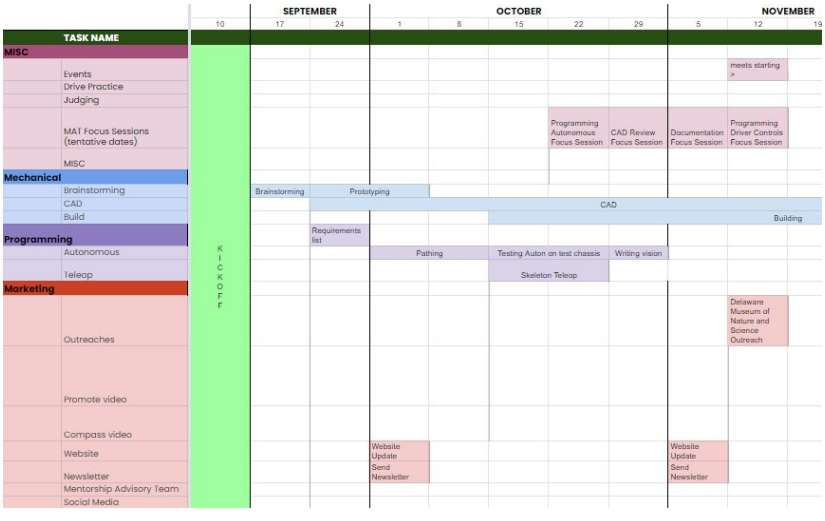
Arnav Prasad
MOE Alum/ Mentor

Superpower: “Having too much free time”

MISSION Team Plan

Goals After performing a SWOT analysis, we defined goals based on the features of our team we identified. While we did not meet every goal, we learned valuable lessons which we will apply in future seasons.

	GOAL	OUTCOME
STRENGTHS	**Sponsors:** Strengthen connections with existing sponsors and attain 2 new sponsors.	Connected with new sponsor, Haas Foundation, and interacted more with REV via social media.
STRENGTHS	**Documentation**: Streamline our documentation templates for efficiency and maintain documentation consistency with better tracking.	Revised templates, focused on writing specific and concise notes. Created a monthly “sign-off sheet” to track progress of all notebook entries.
WEAKNESSES	**Social Media Productivity**: Tailor content to our audience and implement a more intentional plan informed by industry standards.	Our Tips Series allowed us to connect with other FTC teams and gain a wider audience. Met with a marketing analyst to learn best practices.
WEAKNESSES	**Time Management:** Reevaluate Gantt chart biweekly, and hold any extra meetings needed to meet key checkpoints earlier in the season.	Held meetings to review the Gantt chart about monthly, improved team communication but still fell behind on our mechanical timeline.
OPPORTUNITIES	**Skill Building**: Develop cross-functional skills by having marketing team construct a new outreach bot and all students contribute to outreach.	Marketing team programmed and maintained two robots used in outreach events. All students participated in outreach.
OPPORTUNITIES	**Current and New Relationships**: Maintain long-term relationship with Hagley, and start a new relationship with a community organization.	Renewed relationship with Hagley through two events, and reestablished a relationship with Delaware Museum of Nature and Science.
THREATS	**DE FTC Sustainability**: Support long-term sustainability of DE FTC by creating resources for starting new teams.	Created an info packet for potential new teams and distributed flyers, provided information to a graduating FLL team, attended FLL events, and planned for future recruiting.
THREATS	**Supply Chain Issues:** Focus on simplicity when designing, design faster to allow for shipping.	Designed with parts we could machine or 3DP, but at times included too much complexity.

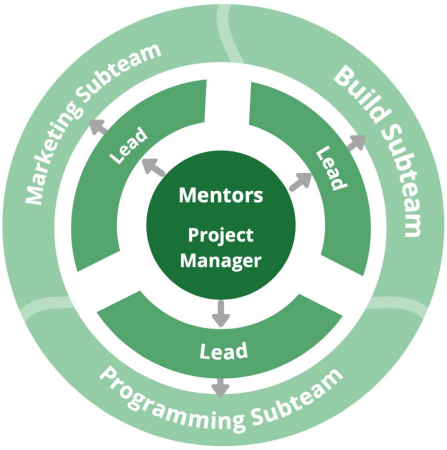


Scheduling

In order to stay on track with our goals and meet important deadlines, each subteam maps their plans and key checkpoints on a Gantt chart, supervised by the project manager. At review meetings, we sometimes must adjust schedules mid-season while considering that certain checkpoints, such as starting drive practice, are less negotiable. The Gantt Chart helps us track our goals and efficiently work within the time constraints.

Team Structure

Our team structure is designed to promote responsibility, communication, and leadership. Student 'subteam leads' delegate tasks and provide guidance, and other students take more flexible learning roles to build a strong skill set. Through cross- subteam projects and team bonding activities, we maintain fluidity between these subteams. The project manager leads full-team scheduling and update discussions.



Sustainability

Students **learn skills** by being paired with student leads or mentors who instruct and guide them throughout the season. Several subteams have onboarding guides for incoming students to teach core mechanical, programming, and documentation skills.

With only one student graduating our team this year and last year, we shifted our focus to **recruiting for new Delaware teams**. We created an info packet for potential teams and began distributing information to schools and local organizations. We are planning to repeat our open application recruiting process this spring to find new students, and to continue individually contacting potential new coaches and parent organizations to grow the Delaware FTC program and aid our FTC region's long-term sustainability.

Partnerships and Sponsors

Our current sponsors are:

First State Robotics (FSR): non-profit parent organization since 2007. We provide team updates and documentation.

DuPont/ Corteva: lab space, tools, and financial support. since 2007. We provide reports through FSR.

REV: store credit since 2021. We reapply each year to Team REV and give updates via social media and monthly surveys.

Labware: financial support since 2011. We give email updates.

Gene Haas Foundation: new this season, financial support. We connected by networking with foundation representatives at World Championships last season and by applying online.

Boeing: mentorship and financial support. We attend company events and provide updates.

We've also developed partnerships with:

Hagley: Since 2018, we have demonstrated robots at summer camps, Science Saturdays, and Halloween events.

Delaware Museum of Nature and Science: We reconnected after they reopened from renovation this year. We bring robots to Scout Days, museum days, and special community events.

Mentorship Advisory Team

This year, we wanted to better connect with industry professionals to learn best practices, explore potential careers, build skills, and improve our outcomes. We achieved this by creating a mentorship advisory team (MAT), with experts in engineering, programming, documentation, management, marketing, computer aided design (CAD), etc.

We recruited mentors by distributing information at outreach events and by sending emails to personal contacts and encouraging them to share. MAT currently has 15 mentors in diverse fields. In 5 focus sessions, we presented about our team's current processes and asked mentors about how we could improve. Some key learnings are listed below:

- Research modern vision libraries like Pure Pursuit.
- Consult programmers often when CADing.
- Create bimonthly documentation summaries.
- Make Gantt chart checkpoints more visible to all.
- Prioritize social media content pillars and consistency.

Finances

While team finances are primarily handled by mentors, students get involved by attending periodical reviews, documenting purchase orders of mechanical parts, and contacting sponsors. Recent pandemic seasons have decreased our expenses, providing us with a large carry over fund that enabled us to invest in CNC router and fund new Delaware FTC teams.

Estimated Income	Estimated
Sponsors	
LabWare	$5,000
Boeing	$800
DuPont	$5,000
Misc.	
Students	$1,950
Boeing Gift Match	$3,000
Carry Over from Previous Year	$19,509
Income Total	$35,259

Estimated Expenses	Estimated
Registration Fees	
FIRST® Registration	$295
DSFTC Registration	$250
Competition Entry Fees	$2,000
Parts	
General Parts	$7,000
REV: Control/ Expansion Hub	$300
General Tools	$1,500
Misc.	
Website/Domain	$144
Outreach Materials	$300
End of Year Party / Team Bonding	$1,000
Spirit Gear - Team Jackets	$600
Competition Food	$200
Expense Total	$13,589

Future Plans

- Upcoming events at Hagley Museum and Delaware Museum of Nature and Science.
- Run another recruiting cycle, distributing flyers and application materials, to find new DEFTC students.
- Contact schools and organizations that might host a new FTC team and work with them over the summer.
- Create season summary and robot reveal video to show to community members and sponsors.

Student Reflections

“I have a learned a lot from this new experience. Being part of such a welcoming and hardworking team has allowed me to understand the importance of teamwork and patience.” - Pranavi

“This year, our team pushed to connect with new programs, allowing me to improve my organization and correspondence skills through a number of outreach events and volunteering opportunities.” - Victoria

“As a returning member, being a part of the team has enabled me to further understand the importance of teamwork, connections, and integration as the season progressed” - Derek

“Since this is my third year on the team and I’m now a more experienced member, I’ve learned more about leadership and the organizational side of building a robot. This season has taught me a lot about how important skills beyond just designing, building, and programming are to creating a robot.” - Ethan

“I was the sole senior this year, which was a scary responsibility! I learned to balance both taking charge and delegating tasks to my teammates. I especially practiced coordinating a schedule dependent on many people. ” -Clare

“This year, since our programming and build teams have become more integrated, I learned much more about how our robot works as a whole, both programmatically and mechanically. This helped me develop new skills surrounding practical problem solving and design.” -Jonathan

OUTREACH Introduction

GOALS

In accordance with our mission statement, our team aims to spread our passion for STEM and use our resources to help others achieve more.

We defined three focuses for outreach this season: establishing **mentorship** relationships with industry professionals, **empowering** youth of all backgrounds to get involved in STEM, and building strong FIRST **community**.

To track the impact of our outreach, we fill out a documentation entry for each event to record statistics, reflect on the experience, and note lessons we learned.

OUTCOMES

MENTORSHIP

Learning from industry professionals to improve our processes and explore future careers. The Mentorship Advisory Team consists of 15 professionals in areas including programming, CAD review, marketing, etc. Through the focus session meetings, our team is learning how to refine our processes to a more professional level.

CAD Review Focus Session - October 2022

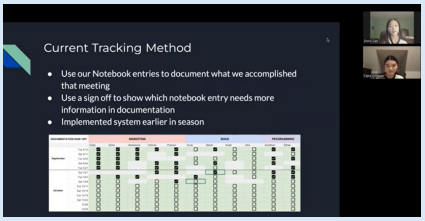
Mechanical team members discussed our CAD review processes. We learned how to ensure that the CAD design integrates well with the programmers and how to make preliminary plans for building.

Programming Autonomous Focus session - October 2022

The programming team compared the pros and cons of several different localization/vision solutions. MAT members discussed industry-standard best practices for researching and using libraries.

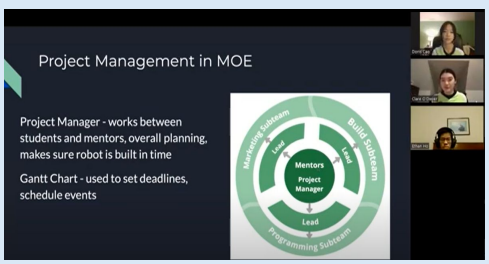
Documentation Focus Session - November 2022

Each subteam lead attended this focus session to discuss the best documentation methods specific to their area. MAT members advised us to summarize progress quarterly and use the notebook to learn about other subteams' activities.



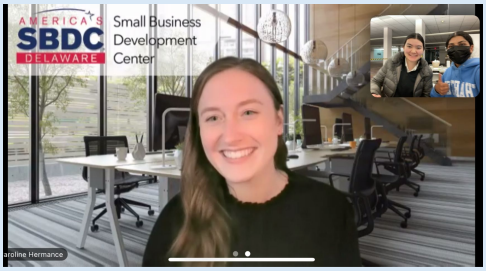
Project Management Focus Session - December 2022

Each subteam lead attended this focus session, so we could discuss with the MAT members how each subteam could help contribute to ensure that the team remains on track. MAT members highlighted the importance of keeping the Gantt chart visible, revisiting deadlines, and having regular progress check ins.



Marketing Focus Session - February 2023

Caroline, an advisor from UD's Small Business Development Center, reviewed our social media accounts and gave us tips on how to create a posting strategy and plan content pillars. We learned to focus on consistency, include more human faces, and reshare other team's posts to strengthen FTC's presence as a whole.



OUTREACH Empowerment

EMPOWERMENT

Inspiring local youth to pursue STEM by presenting robot demonstrations and connecting with families.

Future Plans

- Delaware Museum of Nature and Science Star Wars event on May 6
- Hagley's July summer camps and September Science Saturday

Hagley STEM Camp and Invention Convention | April, July

In these events at Hagley, we presented programming concepts to kids, demonstrated our past competition bots, and collected contact information from interested parents to send them FLL info.

"This was a really fun experience that allowed me to improve my presentation skills." - Aishwarya

Delaware Car Show | June

At the State Fairgrounds, we worked with #12880 Razor Steel to showcase our robots to many age ranges along with promoting the introduction of FIRST in the southern Delaware community.

Delaware Museum of Nature and Science | November

We showcased the Ultimate Goal robot to younger children who might be interested in FLL, primarily Girl Scouts, along with gaining connections with mentors and schools.

"I really enjoyed showing the kids the robot and speaking to their parents about teams and mentors" - Pranavi

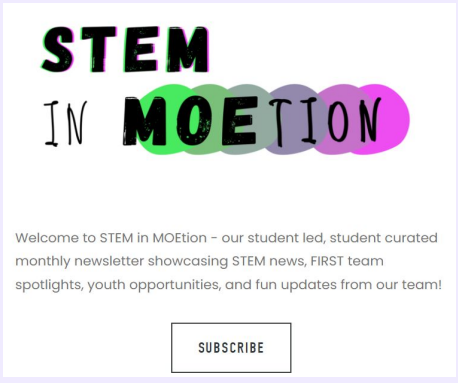
Chemistry Week | December

We were invited by the Delaware ACS Section to attend the National Chemistry Week Children's Event. We talked with parents and taught kids to drive our robot through obstacles.

"I loved having a lot of long, meaningful conversations about the benefits of FIRST programs and how they have helped me develop my skills" - Doris

Newsletter | Ongoing

This was the third year of our team's newsletter. We write blogs about our experiences with STEM, spread news, and give updates on our team. At outreach events, we encouraged parents in our community to subscribe and receive updates about our team and other youth STEM opportunities. This season we published 4 new editions to over 60 subscribers.



"Through the 4 editions this season, I learned how to improve my coordination and organizational skills by assembling many team members' efforts into newsletter sections." - Jonathan

OUTREACH	Kids & Parents	Duration (hrs)
Hagley Invention Convention	130	7
Delaware Car Show	20	4
Hagley STEM Camp	15	1.5
Delaware Museum of Nature and Science Outreach	55	4.5
Delaware Museum of Nature and Science Girl Scouts Event	90	2
Chemistry Week	70	3
Newsletter (4 editions)	60	8
TOTALS:	440	30

OUTREACH Community

COMMUNITY

Building the FIRST community through skill-sharing, networking, and new team development.

Kickoff Presentation - September 2022

We presented to other Delaware FTC teams about the objectives of outreach, how to find events, and ideas for impactful local outreach.

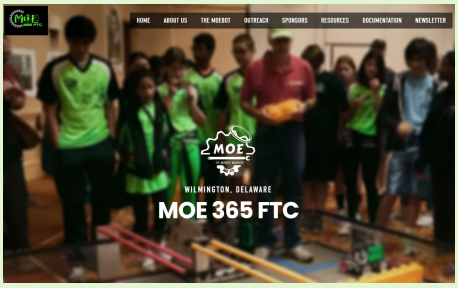
FLL Volunteering - January 2023

We volunteered at a FLL qualifier where we talked to the kids about further exploring STEM through FTC programs.

"I loved seeing how these kids were already passionate about STEM from FLL, and how we could inspire them to further explore their interests in FTC."
- Doris

Online Resources | Ongoing

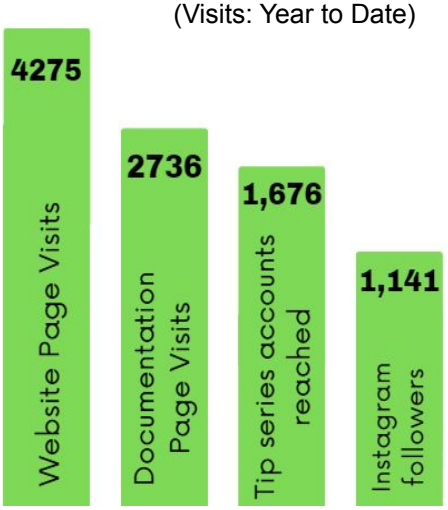
We continued adding helpful information for other teams to our website, including documentation templates, past notebooks, and outreach examples.



New Team Recruiting | Ongoing

One of our goals this season was to expand the FTC program in Delaware. We created an information packet and flyer and started to distribute these resources to local schools and organizations.

Website/Instagram Statistics
(Visits: Year to Date)



COMMUNITY BUILDING EVENTS	FIRST Community Members Reached	Duration (hrs)
Outreach Presentation at Kickoff	30	.5
Making Cookies with FTC and FLL teams	15	1
Volunteering at FLL Qualifier	50	6
Volunteering at FLL Championship	35	4.5
Meeting with FLL team LOAD robotics	5	1.5
TOTALS:	135	13.5

Tips Video Series | Ongoing

We created a tip series video on Instagram because we wanted to help newer teams learn more about FIRST. We created videos on setting goals, guiding your team through a SWOT analysis, engineering processes, and more.

Future Plans

- Running a recruiting cycle to find more interested students
- Reaching out to organizations to start new teams for next season, by distributing our info packet and flyers

Design Principles

Design Process Overview

This season we utilized a design process similar to the previous year's, to guide us throughout the robot design and build process. Each step is equally important, and the process is designed to be iterable - meaning that if we reach the testing phase and our part fails, we can go right back into brainstorming.

Our two main design principles, Designated Subsystems and CAD First, are explained on the right.

Designated Subsystems

Our mechanisms can be both designed and assembled independently, allowing multiple instances of the design process to happen **simultaneously.** In order to make this possible, we utilize **standardized hole spacings** on any custom plates, **COTS** kit parts, and **slot/extrusion** based systems. This also allows our robot to be **easily maintainable** and **adaptable** to future changes.

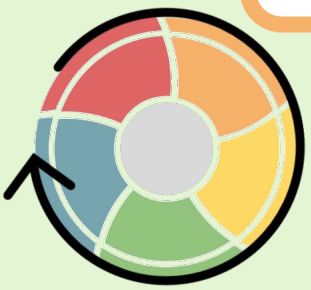
CAD First

Aside from temporary prototypes, a large emphasis is placed on designing in Computer Aided Design (CAD) software before implementation. This ensures everything **fits together properly** before spending time and resources on implementation. It also allows for greater efficiency in our meetings, as the majority of the design work can be done at home. CAD also allows for custom 3D printed and machined parts.

Brainstorming
Concepts are generated.

Prototyping
Concepts are quickly developed then evaluated for their effectiveness and simplicity.

Testing
Effectiveness of mechanisms are recorded and analyzed.



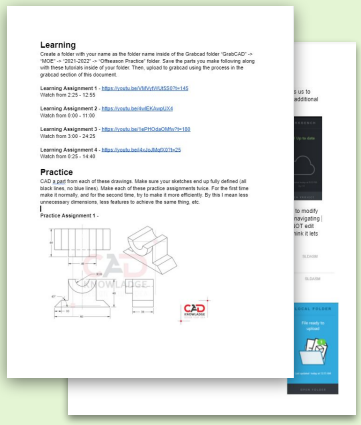
Designing/CAD
CAD models are developed using information gathered from prototypes.

Implementation
Physical mechanisms are manufactured and assembled with CAD models used as reference.

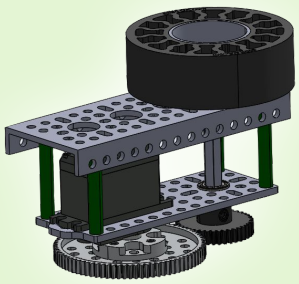
Making changes to the design of the robot requires faster prototyping, testing, and redesigning. Throughout the course of the season, we have changed through three different lifts and learned to more quickly implement the better design.

Tape Measure Lift: 3 months
String Lift: 2 weeks
Sprocket Chain Cascade: 2 wks

Solidworks Tutorial Documents



Practice CAD Project

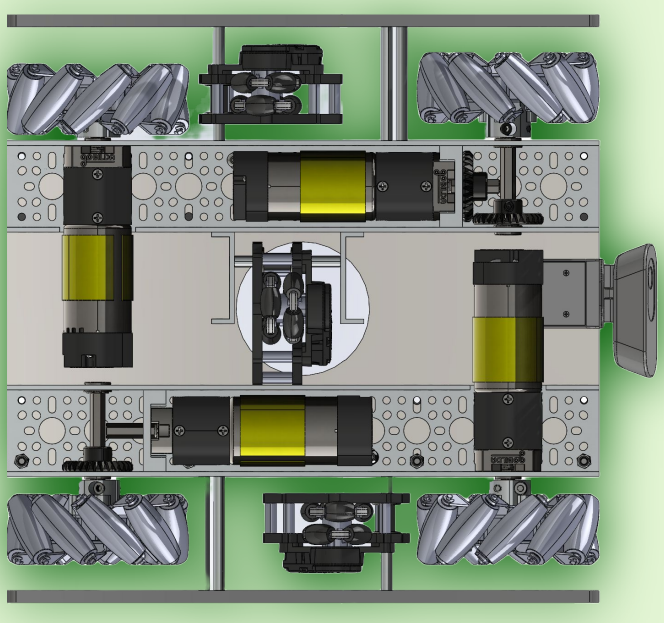


Our veteran design members taught CAD to current and new members in several ways:

- CAD Lesson plan
- CAD Demos
- CAD Projects

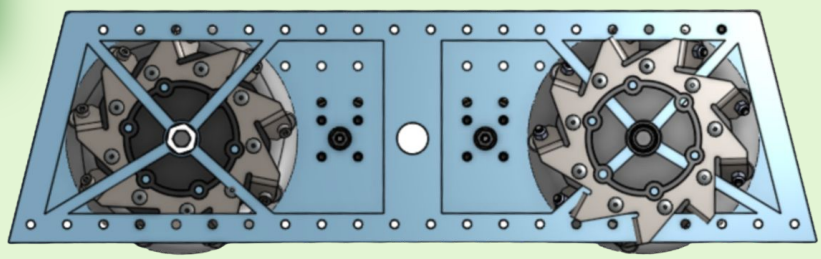
"I faced a challenge of not knowing how to make complicated CAD models from scratch. Using previous years' games as practice, Derek showed me how to design assemblies to solve challenges." - Suraj

Brainstorming

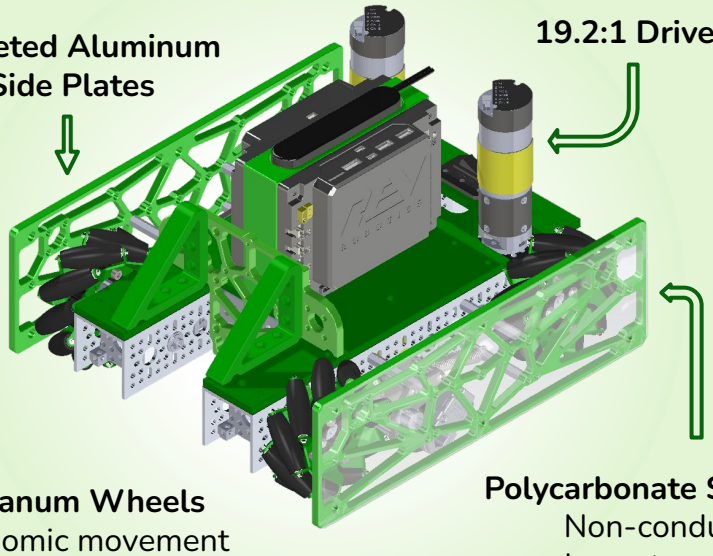


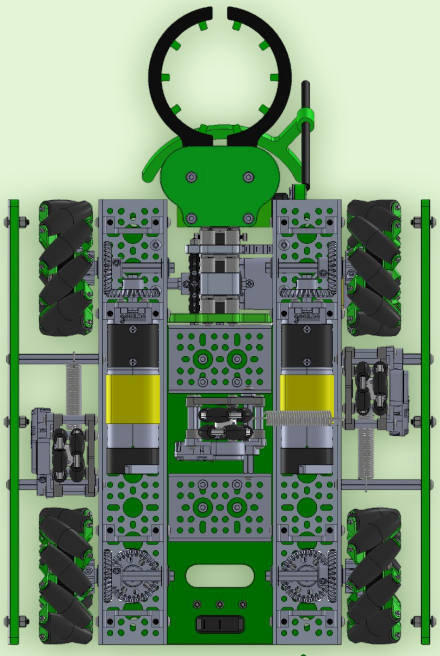
Compact and Versatile Design

With the obstacle of junctions, having a smaller and more compact drivetrain is easiest for our drivers. Moreover, we decided on mecanum wheels due to their flexibility and ability to strafe, enabling quick turns and maneuvering.



Current Chassis





Mecanum Drivetrain

Holonomic → Easy, flexible movement.
Strafing is necessary to navigate the grid of junctions obstructing our movement.

Motor Layout

With perpendicular and vertical motor layouts, the chassis becomes more compact, enabling the bot to fit between the junctions more easily.

DESIGN Cone Control

Junction Stabilizer

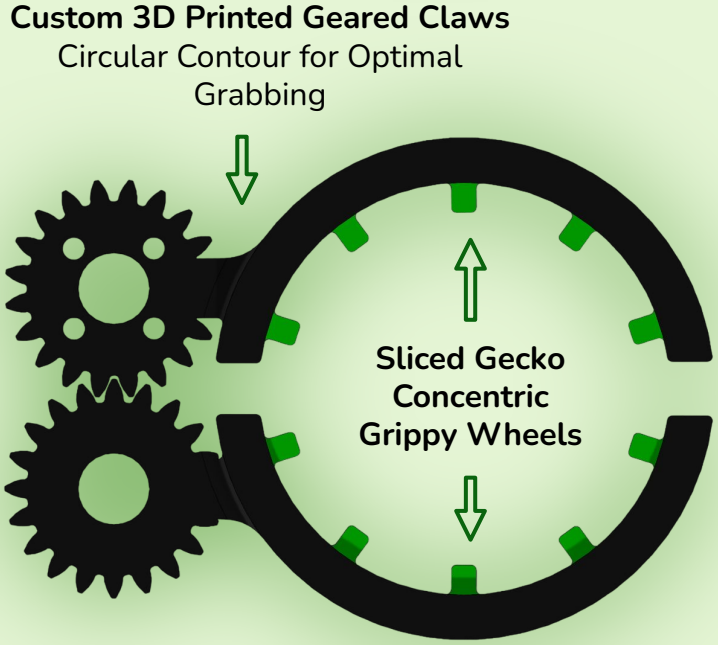
For precise cone placement, our junction stabilizer helps center the robot against junctions when scoring. It is 3D printed with a specific semi circle shape with a diameter of 4.25”. The stabilizer is connected via a lightweight carbon fiber stick, which has essential mechanical properties to be able to withstand high impact forces.

Claw

Our 3D printed PLA claw is powered by an Axon Mini servo through a custom collar connector, allowing the claw to be cleanly attached to the Unitak slidestack.

Claw Design Iterations

After testing many different claw ideas, including different sizes, a hexagonal shape, and variety of rubber like-materials, we arrived at our most effective design. A **circular shape** lined with **grippy concentric gecko wheels** allows the claw mechanism to consistently grab and hold onto cones.



Beacon

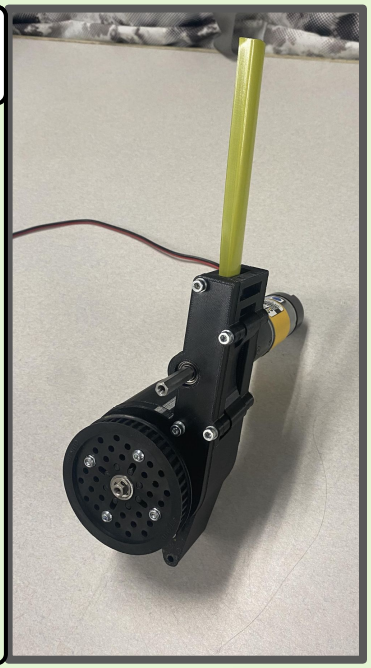
Hexagonal Exterior
For Easier Gripping

Funnel-Like Shape
For Easy and Secure Placement

Powering the Lift

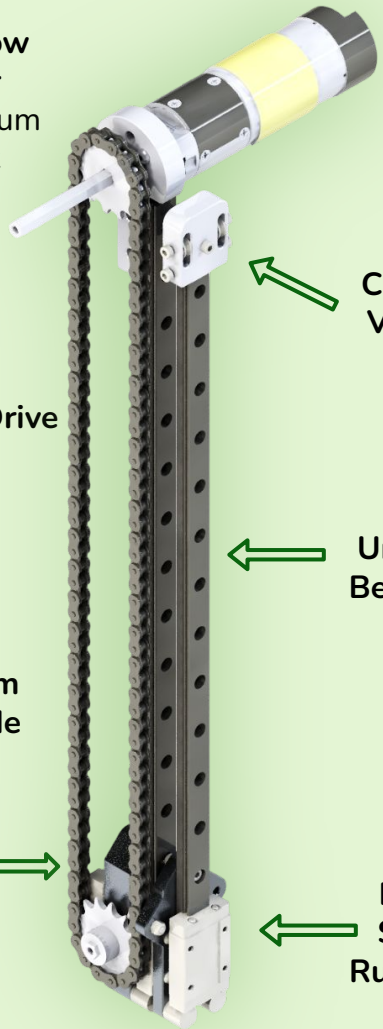
Design V1: Tape Measure

Early in the season, we thought that a tape measure could push and pull the lift up and down, resulting in a reliable lift mechanism. However, after testing, we found that this design was not robust; The tape measure often unspooled through small gaps at the base of the track, damaging our lift and causing it to fail.



Design V2: String Lift

We improved our design with a more conventional string lift, but it still had many inconsistencies. Due to the weight of the previous virtual 4 bar design and the need for 5+ stages of slides, the lift swayed left and right, making scoring cones very difficult. These issues showed us the importance of stability and rigidity, which led to our final design below.



Current Design

After three designs, we found this third design, with the combination of cascade and sprocket chain, to be the most **reliable** and capable for **efficiently delivering** the cones onto every type of junction.

Sprocket Chain to Cascade Lift

Because the V2 string lift design proved to be efficient, we made this third version transition from sprocket chain to cascade string lift.

With the combined **rigidity** of the Unitak linear slides, **reliability** of the sprocket chain, and **robustness** of the string, the robot is able to not only efficiently lift the cone to the top of the junction, but also has limited swaying.

Game Strategy

Teamwork

Teamwork is vital due to the high level of strategy and variance every game. We must work with our teammates to secure circuits and control junctions. We coordinate with our alliance regarding:

- Junction ownership
- Circuit building
- Targeted junction
- Intaking timing

Scouting Strategy

We record valuable information on other **Delaware FTC Teams at State Championships.**

- **Points scored** in scouted games
- **Reliability** of crucial mechanics
- Team scoring **priorities**

Scouting allows us to craft strategies with other teams before matches to maximize the overall capabilities of our alliance.

Scoring Priorities

Auton

Scoring

Delivering Cones to Junctions

- Focus on the *High Junction* for maximum points
- Mid-High Priority

Parking

Highly prioritize parking in the correct zone

TeleOp

Scoring

- Prioritize high-junction for maximum points
- Secondarily focus on uncontrolled mid-junctions
- Low and floor junctions are low priority

Controlling

- Junction control is difficult to guarantee early on, however it awards many points, so spreading out control is high priority

Circuit Building

- Circuit's are difficult to maintain in teleOp, so they are deprioritized early on
- Circuit building is left for endgame

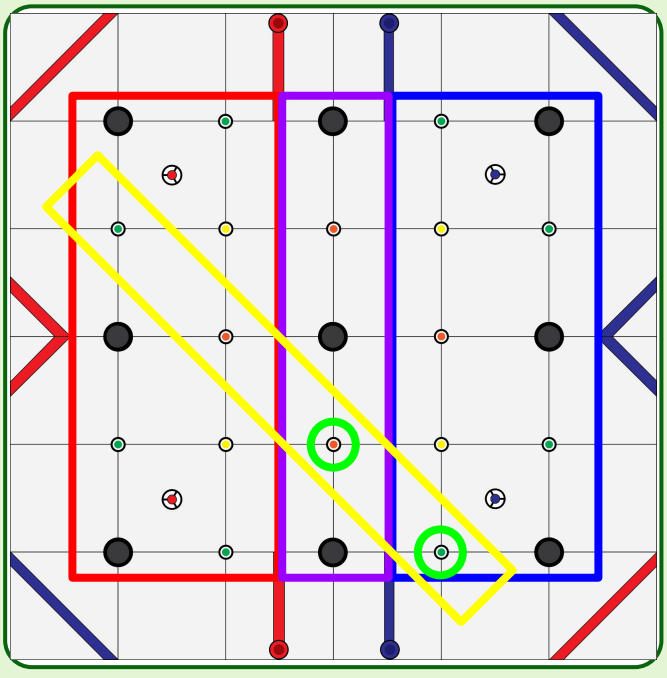
Endgame

Beacons

Prioritize immediately placing a beacon on the most valuable junctions (denoted in green on the diagram below)

Finalizing Circuits

Secondarily focus on controlling the remaining Junctions needed to complete a circuit



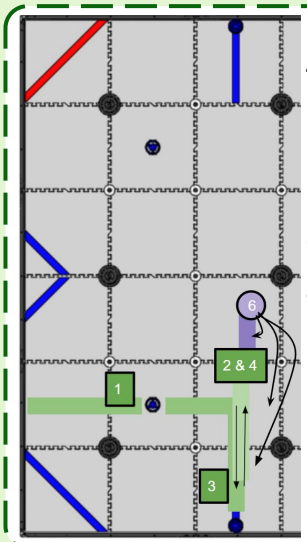
Circuit-Building Strategy (Red Alliance perspective)

The Blue and Red zones represent where it is easier for the Blue and Red alliances to score due to proximity to their substation. Purple represents a contested zone where both teams have equal access to the junctions. It will be much easier for teams to maintain control of junctions within their own zones, which informs our circuit building strategy.

We concluded that the Yellow diagonal is the most effective scoring zone for the completion of a circuit, since it starts close to our Substation and runs directly between our two Terminals.

The Green circles indicate the most effective Junctions to place our Beacons, improving our odds of completing a circuit.

PROGRAMMING Auton

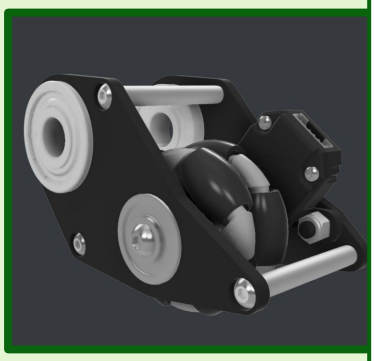


Autonomous Path:

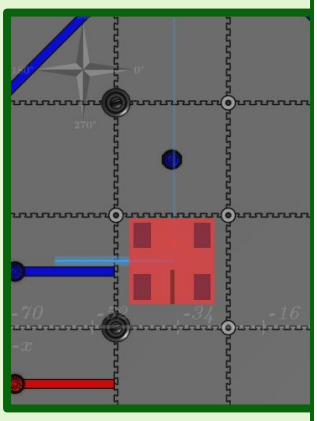
1. Detect Signal
2. Deposit Preload
3. Grab cone
4. Deposit cone
5. Repeat 3-4 3x
6. Park

Autonomous Goals:

Our main goal this year was to be able to cycle as many cones as possible onto the high junction, and park as **consistently** as possible. To achieve this consistency, we needed an accurate way to track our movement and make sure we are always reaching our desired location every single time. This led us to decide on using three **odometry dead wheels** to provide data for our **Roadrunner** which controls our movement.



Odometry Wheels are non-powered wheels bound to an encoder and sprung into the ground that allow for accurate measurement of the robot's movement. Using this data, we can accurately track the robot's movement even if the robot slips or is pushed. This gives a very robust method of localization during autonomous to ensure accurate pathing.



Roadrunner is an advanced motion profiling library developed for FTC which receives data from our odometry dead wheels to analyze the position and construct an optimal path to our predefined coordinates. This allows us to quickly and consistently move along our paths in autonomous.

Previous Alternative - Custom Tensorflow Contour Detection

Last year, we trained our own custom model in order to detect the autonomous randomization; however we encountered consistency issues - especially in different lighting conditions. This led us to using AprilTags this year, which, being an industry standard pretrained model, means that it will be far more robust than our previous solution.

AprilTags (OpenCV)

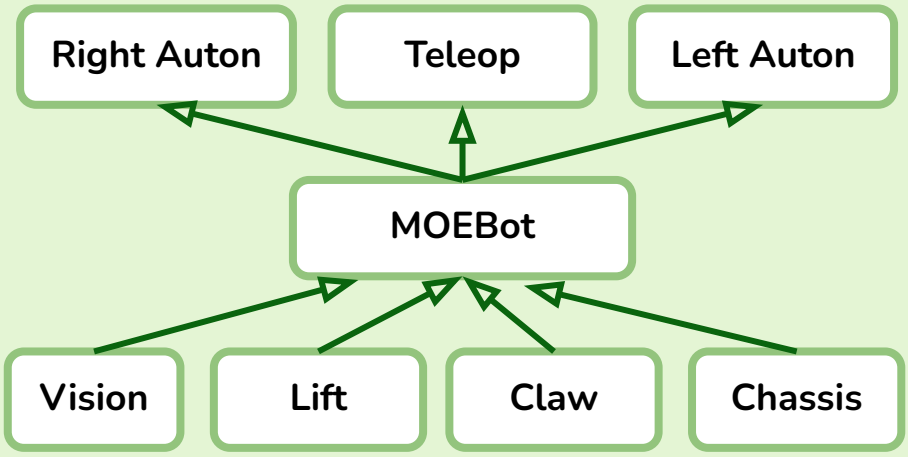
A versatile vision solution that allows for quick and robust image analysis utilizing a wide family of unique “April Tag” markers. Each marker can be detected and identified through a custom OpenCV vision pipeline which processes inputs from webcam frames.

Uses - Open CV’s ability to quickly analyze image frames allows us to use a custom April Tag Detection pipeline to locate a specific tag in an image and then compare that tag with pre-existing IDs. Through this, we are able to identify the Signal’s orientation by identifying the printed April Tag facing the robot.

PROGRAMMING TeleOp

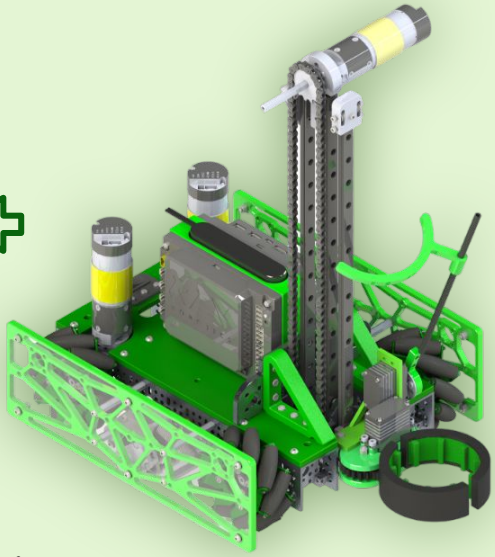
Code Structure:

We organized the code for each of our mechanisms into individual classes with functions for every behavior we needed. This allowed us to have a single 'MOEBot' class that implemented all of these functions that could be easily used in all our opmodes.



Driver Control:

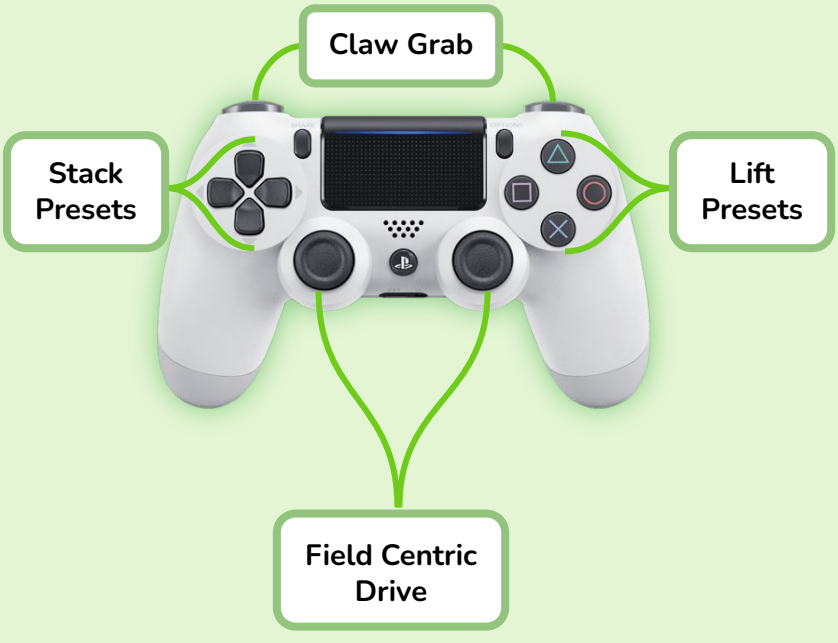
We have preset slide extension positions for each junction height to streamline the driving process. Additionally, our stabilization fork is deployed and retracted automatically at certain heights when the claw is in a safe position.



Safeties:

In order to prevent issues, we have restrictions on when certain actions can be performed based on the position of other mechanisms. For example, we restricted the motion of our stabilizer fork to prevent it from engaging while our lift position is too low or our claw is open.

Gamepad 1



Gamepad 2